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Emerging Technologies Report

Air-Side Economizer Control Strategies[1]

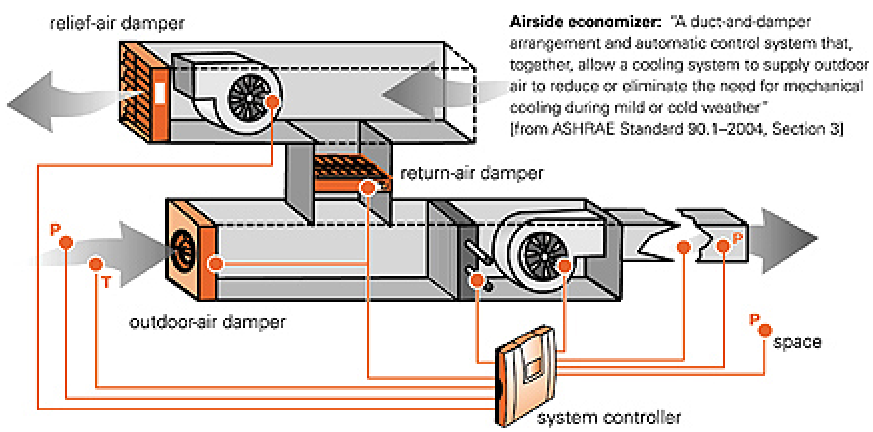
Summary:

Definition	Roof-top air conditioning unit (RTU) with factory-integrated economizer.				
Base Case	Ten-ton unit, inoperative or absent economizer				
New Measure:	Roof-top air conditioning unit (RTU) with factory-integrated economizer	Percent savings	2025 Savings TBtu (Source)	Cost of Saved Energy, $/MMBtu	Success Rating (1-5)
		16%	117	$7.58	3

Background and Description

To maintain the indoor air quality of a building, outside air needs to be introduced for ventilation and mixed with re-circulated indoor air. The mixed air then has to be conditioned to meet the needs of the building.[2] Thus, commercial buildings generally make provision for introducing outside air through dampers connected to the HVAC system. *Air-side economizers* just refers to the use of additional outdoor air when conditions are favorable to supplement or replace the cooling or heating equipment. For example, anytime it is cool outside when there are large internal loads, outdoor air can be used instead of the air conditioning compressors. In addition, in climates with large diurnal temperature swings, aggressive nighttime economizer operation will "precool" the building, by storing "coolth" in the mass of the building and its furnishings. Thus, the savings potential is climate-dependent. But, it is independent of the rated efficiency of unitary air conditioners, such as roof-top units (RTUs), since their efficiency metrics only reflect the refrigeration cycle.

Air-side economizers use ducts to move the air, dampers to control the flow of the various airstreams, and control systems to control the dampers. The control systems can be integrated with the air conditioning system so that the operation of both the economizer and the air conditioning system can be optimized to reduce energy consumption.



http://www.achrnews.com/Articles/Technical/8feb3c885a7bc010VgnVCM100000f932a8c0____

[1] This report treats new equipment only. Some of the strategies described are relevant to retrofits, particularly for larger units.

[2] Alternatively, the outdoor air can be conditioned pror to intoroduction to the zones, as is done with *Dedicated Outdoor Air Systems.*

An air-side economizer should only be used when the outside air conditions are suitably cold and/or dry. Drawing in warm and humid outside air will increase the cooling and dehumidification load on the HVAC system, resulting in increased energy consumption. There is thus a need for accurate and effective air-side economizer control systems. There are 2 types of control systems in common usage today: dry bulb temperature sensors and enthalpy sensors.

Dry bulb temperature sensors measure the sensible temperature of the surrounding air. These sensors activate the economizer whenever the outside air temperature is below the set temperature.

Enthalpy sensors measure the total sensible and latent (water vapor) energy load of the air. This the economizer from operating under cool but humid outdoor conditions, when additional outdoor air would require additional air conditioning to remove the humidity. Enthalpy controls come in fixed and electronic forms. Fixed enthalpy controls turn the economizer off whenever the calculated enthalpy (sensible + latent heat content) of the outside air exceeds a set enthalpy. Electronic enthalpy controls compare the measured temperature and humidity against a programmed range of temperature – humidity set points and disable the economizer when the outdoor air enthalpy (temperature and humidity combined) exceed the programmed range.

Both dry bulb and enthalpy controls can be implemented with a single set of sensors to detect the air conditions of the outdoor air, or with a second set of sensors to compare outdoor and return air conditions. The dual sensor system, known as differential dry bulb control or differential enthalpy control, allows the economizer system to compare the temperature or enthalpy of the outdoor air to that of the return air and to select the air stream with the lower temperature or enthalpy for air conditioning. These differential controls are more expensive, but they can improve the performance of the economizer system by only allowing suitable outdoor air in (beyond that required for ventilation, of course). This can result in lower energy consumption by the HVAC system.

Limitations of Existing Economizer Sensors

Dry bulb sensors are only able to measure the sensible load. They are unable to detect the latent (moisture) load in the air. As such, these sensors may allow cool but overly moist outdoor air to enter the building, which could result in increased energy consumption (due to the need for dehumidification), health issues (e.g. mold growth) and discomfort. Dry bulb sensors are thus unsuitable in humid climates.

Enthalpy sensors measure the total energy load by combining information on temperature and relative humidity. However, enthalpy measurements alone cannot provide information on the latent load. Other concerns with enthalpy sensors include the fact that enthalpy is affected by local barometric pressure and elevation (an error of 2% in the enthalpy value calculated can occur per 1000 feet of elevation[3]) as well as the accuracy of the sensors.

Dew Point and Dry Bulb Sensors

The dew point is the temperature at which the moisture in the air condenses. Passing air across a surface that is colder than the dew point will lead to water condensing on the surface. On suitable surfaces, this could result in mold and other moisture problems. Measuring the dew point of the outside air and programming the economizer to allow only air that has a dew point lower than that of the surfaces within the building to be brought in can help to prevent the introduction of overly moist air into the building.

The table below summarizes the relative advantages and disadvantages of the various control strategies.

[3] AirTest "Economizer Control Design Guide: A White Paper"

CONTROL STRATEGY	ADVANTAGES	DISADVANTAGES
Fixed dry bulb	Inexpensive Suitable for dry climates	Considers only sensible load Not suited to humid climates
Differential dry bulb	Improved performance over fixed dry bulb Suitable for dry climates	Slightly more expensive than fixed dry bulb Not suited to humid climates
Single enthalpy sensor	Considers total load (sensible and latent) Improved performance over fixed dry bulb More suited to humid climates than dry bulb	More expensive than fixed dry bulb Does not separately consider sensible and latent load Accuracy is an issue
Differential enthalpy	Considers total load (sensible and latent) Improved performance over single enthalpy sensor More suited to humid climates than dry bulb	Slightly more expensive than single enthalpy sensor Does not separately consider sensible and latent load Accuracy is an issue
Dew point and dry bulb	Separately considers sensible and latent load Improved performance over dry bulb and enthalpy sensors High accuracy Better able to address humid conditions than dry bulb and enthalpy sensors	More expensive than dry bulb and enthalpy sensors

Data Summary

Market Sector	Market Application		End Use		Fuel Type
Commercial	New/Replace on Burnout Long Life		Cooling		Electricity
Current Status	**Date of Commercialization**		**Product Life (years)**	**Source**	
Commercialized			15	Higgins 2003	
Basecase Energy Use		**Units**	**Notes, Explanation**	**Source**	
Efficiency	11.00	EER	ASHRAE 90.1-2007 minimum as of 1/1/2010		
Electricity Use	16,400	kWh/year	Assume no economizer in FEMP calculator	FEMP calculator	
Summer Peak Demand	9.8	kW	0.9 coincidence, EER = 12/(kW/ton)		
Fuel Use	0	MMBtu/year			
New Measure Energy Use					
Efficiency	13.20	effective EER	Assume nat. average 20% improvement w. economizer, net of increased fan power		
Electricity Use	13,700	kWh/year			
Summer Peak Demand	8.2	kW	0.9 coincidence		
Fuel Use	0.0	MMBtu/year			
Savings					
Electricity Savings	2,700	kWh/year			
Summer Peak Demand Svgs	1.6	kW			
Winter Peak Demand Svgs	N/A	kW			
Fuel Savings	0.0	MMBtu/year			
Percent Savings	16%				
Percent Feasible	38%		70% of packaged units (54% of total commercial cooling load)		
Industrial Savings > 25%?	No				
Costs					
Incremental Cost	$ 2,300	2008 $	Frankenfield estimate for incremental price, catalogue for economizer with control	GEG, 2003	
Other Costs/ (Savings)	0	$/ year			
Ranking Metrics					
2025 Savings Potential	11,131	GWh			
2025 Savings Potential	117	TBtu			
Cost of Saved Energy	$ 0.079	$/kWh			
Cost of Saved Energy	$ 7.58	$/MMBtu			

Unusual Market Barriers	Non-Energy Benefits		Current Activity	Next Steps
Fast Payback Concerns Uncertainty about economizer benefit sustainability	Increases average ventilation rate		WECC specification Manufacturer promotions	Incentives
Likelihood of Success	3	(1-5)		
Priority	Special	Low, Med, High		
Data Quality Assessment	B	(A-D)		
Principal Contacts				
Peter Jacobs, Architectural Energy				
Cathy Higgins, New Buildings Institute				
Marshal Hunt, WCEC				

Current Status of Measure

Air-side economizers are required in many locales by the building code. They are required for cooling systems in commercial buildings by the 2006 International Energy Conservation Code, depending on climate zone and cooling system capacity.[4] The use of economizers is also required under ASHRAE Standard 90.1-2004 (section 6.5.1), although exceptions are made for some situations (see Appendix). It is estimated that about 60% of buildings in the US utilize economizers. Still, ACEEE regards air-side economizers as emerging technologies because field performance of available products has been very poor. In a significant California study that included 123 economizer-equipped roof-top units, 63% had substantial operational problems, and most of these had field-installed economizers instead of factory-integrated units.[5] California now requires integrated air-side economizers on commercial equipment above 75,000 Btu/h.[6]

There are some incentive programs available to encourage the installation of economizers. Some of these programs, such as NYSERDA, require the installation of differential enthalpy economizer controls.

Energy Savings and Costs

Air-side economizers have enormous cumulative energy savings potential – almost 0.2 Quad, but the savings vary from very large in drier climates with good diurnal temperature swings to minimal in hot-humid climates where outdoor enthalpy is too high for effective cooling. We estimate the cost of saved energy as <$0.08/kWh.

Key Assumptions used in Analysis

Average Price of Electricity	$0.1032/kWh[7]
Average Price of Natural Gas	$10.97/MMBtu[8]
Real Discount Rate	4.53%
Heat Rate	10.48 kBtu/kWh

[4] http://resourcecenter.pnl.gov/cocoon/morf/ResourceCenter/article//1639
[5] Higgins, C. 2003. Integrated Design of Small Commercial HVAC Systems. CEC Project 500-03-082. http://www.energy.ca.gov/pier/project_reports/500-03-082.html
[6] 2005 California Title 24, Part 4. Mechanical systems. http://www.energy.ca.gov/title24/2005standards/nonresidential_manual.html
[7] EIA, "Electric Power Monthly – Feb 2009", (YTD-Nov08, Commercial Price)
[8] http://tonto.eia.doe.gov/dnav/ng/ng_sum_lsum_dcu_nus_m.htm

Our key assumption is that we can extrapolate from the inoperative fraction of California economizers to the savings is a very high fraction of economizers are parts of integrated systems with service expectations equivalent to those of the refrigeration components.

Recommended Next Steps

Today, RTUs are mostly marketed as "boxes," and system integration is left to the mechanical designer and installing contractor. This integration includes controls (either programmable thermostats or building automation interface), economizers, filtration, fan speed, and the critical commissioning step. The conceptual goal is a shift to selling RTUs with the economizer robustly integrated into the unit by the original equipment manufacturer. This is likely to require uniform ways to estimate relative efficiency of RTUs with specific economizer controls by climatic region. As important, it is likely to require reliability testing: a performance specification establishing the that economizer is likely to operate reliably for a given number of year that correspond to a large fraction of the expected unit life.

In the meantime, two approaches are promising:

- **Market Transformation**. ENERGY STAR, FEMP,[9] and the Consortium for Energy Efficiency (CEE) attempt to identify more efficient air conditioners, to help decision makers, and to help utilities and other incentive program operators to coordinate efficiency levels. This makes it easier for manufacturers to focus efforts on what these customers want. The current specifications from CEE do not include economizer specifications; ENERGY STAR's specification is in revision now.[10] The FEMP calculator does not seem to include economizer option benefits. The challenge for these programs is to include key regional features in their national standards.
- **Market Aggregation.** The Western Cooling Challenge[11] has developed a specification for an advanced hot-dry climate roof-top air conditioner, signed up national account retail purchasers, and is testing prototype air conditioners to determine suitability. This should lead to product availability in 2010. One product has already satisfied program conditions. The program target was a 40 percent reduction in energy use and peak electricity demand compared to conventional cooling units, but the first product's tests indicate almost 80 percent energy-use savings and over 60 percent peak-demand reduction..[12] Of course, not all the savings are due to the economizer: the design relies on indirect evaporative cooling rather than economizers for most of the hot-dry climate savings.

Appendix

<u>Exceptions to Economizer Requirements in ASHRAE Standard 90.1-2004:</u>

(a) Systems using fan-cooling units with individual capacities less than 65,000 Btuh (19 kW) in dry climates, less than 135,000 Btuh (40 kW) in cool-moist climates, and with any capacity, large or small, in warm-moist climates.

(b) Systems with gas-phase outdoor air cleaning to meet ASHRAE Standard 62.

(c) Systems that deliver more than 25 percent of the supply air to spaces humidified above 35°F dew point for process needs.

(d) Systems with condenser heat recovery.

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[9] http://www1.eere.energy.gov/femp/technologies/eep_unitary_ac.html
[10] http://www.energystar.gov/index.cfm?c=partners.pt_products_and_program_reqs
[11] http://wcec.ucdavis.edu/content/view/92/110/. Sponsored by the Western Cooling Efficiency Center of the University of California, Davis. http://wcec.ucdavis.edu/
[12] http://www.news.ucdavis.edu/search/news_detail.lasso?id=9200

(e) Any residential space system with a capacity that's less than five times the applicable limit listed in Exception (a).

(f) Systems with space sensible cooling loads (excluding transmission and infiltration loads) equal to or less than transmission and infiltration loads at 60°F.

(g) Systems that are expected to operate less than 20 hours per week.

(h) Supermarket systems where outdoor air for cooling affects open refrigerated cases.

(i) Systems with high mechanical cooling efficiencies.